Substation Automation and Smart Grid

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The Smart Grid

Current Situation

Current IED Penetration

- A little more than half of existing T&D substations are equipped with IEDs


Current Situation (continued)

IED Level of Integration

- 55% of IED substations have no integration (29% of total subs)
- 45% of IED substations have some integration (24% of total)
Plans for “Retrofit” Substations

- 97% of retrofit T&D substations will have IEDs
- 42% of retrofit T&D substations include IED integration and automation

Plans for New Substations

- 97% of T&D substations will have IEDs
- 85% of T&D substations will include IED integration and automation

Why Needed? Why Now?

- DEREGULATION & COMPETITION
  - Deregulation driving actions of most utilities
  - Major driving forces:
    - Improved power quality and service reliability
    - New energy related services and business areas
    - Lower cost of service
    - Information needed for improved decision making
  - SA: A proactive response to these forces
Why Needed? Why Now?

- **DEVELOPMENT OF IEDs**
  - Rapid development and deployment of Intelligent Electronic Devices (IEDs)
  - Protective relays
  - Meters
  - Equipment condition monitors
  - IEDs have become an integral part of Substation Automation systems
  - Technological developments have made SA systems less expensive and more powerful

Why Needed? Why Now?

- **ENTERPRISE-WIDE INTEREST IN INFORMATION FROM IEDs**
  - “Operational” Data
    - Amps, volts, watts, VARs, fault location, switchgear status
  - “Non-Operational” Data
    - Equipment condition
    - Fault event and power quality data (waveforms)
  - Persons working outside the control room want access for improved decision making

Why Needed? Why Now?

- **IMPLEMENTATION AND ACCEPTANCE OF STANDARDS**
  - Confusion over industry communication standards is diminishing
  - International standards have become reality
  - UCA2 ↔ IEC61850
  - Standards based implementation projects underway at many electric utilities
  - Widespread use of de facto standards for IED communications (DNP3, Modbus, Modbus+)
  - Some use of de jure standards (UCA2/IEC61850)
Construction Cost Savings

• Required functionality bundled in fewer components (21, 50/51, 79, …, metering, etc)
• One IED may replace many E-M devices

**Reduction in Physical Complexity**
- Less inter-device wiring
- Fewer unique devices to inventory
- Some traditional devices eliminated altogether
Construction Cost Savings

- Relay/control house size (new construction only)
- Design & construction labor and materials

Integration Level Benefits

Integrated Protection Functions

- **Objective:** Incorporate protection functions in the SA System
  - Basic protection units (IEDs) exchange current/voltage data via high speed LAN
  - Relay trip signals exchanged over LAN

Traditional (Electromechanical) Approach
Integrated Protection Functions

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Integrated IED Approach

Integrated Protection – Breaker Failure

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GE Substation LAN

Integrated Protection – Breaker Failure

GOOSE Messages

Integrated Protection – Breaker Failure

GE Substation LAN

Integrated Protection – Breaker Failure

GOOSE Messages
Automated Functions

Automatic Load Restoration: Supply Line Sectionalizing

- **Nature of the problem**
  - Distribution substations often tapped off supply line without high side breaker or high side protection
  - Considerable load may be out of service until field crews arrive on scene
- **Objectives**
  - Identify faulted section of supply line
  - Isolate faulted section
  - Restore supply to substations fed off unfaulted section of supply line

Supply Line Sectionalizing
Supply Line Sectionalizing

- Permanent Fault Occurs
- Line Protection Operates
- Line Protection Reports Fault Location

System

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Automatic Load Restoration:
“Intelligent” Bus Failover

- **Nature of Problem**
  - When a transformer failure occurs, “simple” bus failover scheme transfers load to healthy transformer
  - “Simple” failover scheme may overload healthy transformer, especially during peak load
  - Some schemes have been disabled because of this
  - Substation firm capacity limited by amount of load that can be carried if a transformer fault occurs
Automatic Load Restoration: “Intelligent” Bus Failover

**Objectives**
- Transfer as much load as possible to 2nd substation transformer
- If necessary, transfer portion of load to alternate substation
- Shed portion of load if necessary

“Intelligent” Bus Failover: How It Works

Transformer Fault Occurs

“Intelligent” Bus Failover: How It Works
“Intelligent” Bus Failover: How It Works

If Necessary

If Necessary

To Adjacent Substation

Restore Load Using Feeder Automation

To Adjacent Substation

Enter Rise Application Functions

Enterprise Application Functions
Disturbance Analysis

*Exploit Inherent Capabilities of IEDs*
- Sequence of Event reporting
- Digital Fault Recorder (DFR)
- Fault Location

[Diagram showing disturbance data from relay IED to computer engineer's desktop]

Intelligent Alarm Processing

- Prioritize alarm information
- Eliminate duplicate & nuisance alarms
- Route alarm info to appropriate party
- "Expert" alarm processing
  - provides more informative and useful alarm messages

[Diagram showing alarm filter and various alarms]

Power Quality Monitoring

- SA System and IEDs able to detect power quality events and report the following information:
  - Harmonic content of the voltage waveform
  - Total harmonic distortion
  - Oscillographic data (waveforms)

[Diagram showing power quality info from IEDs to computer engineer's desktop]
Real-Time Equipment Rating
– Base equipment ratings on actual conditions rather than conservative assumptions
– Squeeze more capacity out of existing equipment
– Example: Transformer “Hot Spot” Monitoring
  • Monitor the true winding hot spot temperature
  • Derive loadability from the results
  • 5 - 10% additional loading can be achieved

Equipment Condition Monitoring
• Continuous On-line Diagnosis of SS Equipment (HV breakers, Transformers)
  • Main objectives
    – Support reliability centered maintenance
    – Find/fix problems earlier
    – Avoid forced (unscheduled) outages
    – Reduce maintenance costs

Equipment Monitoring Devices
• Dissolved Gas in Oil Monitors/Samples
• Moisture Detectors
• Load Tap Changer Monitors
• Partial Discharge/Acoustic Monitors
• Bushing Monitors
• Circuit Breaker Monitors (GIS and OCB)
• Battery Monitors
• Expert System Analyzers
• Protective Relay IEDs (I2t, Breaker timing)
Equipment Condition Monitoring

- **Role of SA**
  - Monitor specialized sensors
  - Perform "expert system" analysis
  - Inform engineers or dispatchers of possible problems
  - Supply "non-operational" data

**Traditional approach:**

- Substation
- Maintenance Office
- Telephone
- Maintenance Management System

**SA approach – Use "Non-Operational Data Path:"

- IED
- Radio tower
- Data Concentrator
- Local HMI
- TCP/IP
- Corp WAN
- Server
- Data Warehouse
- Non-Operational Data